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(12) UK Patent Application (19) GB (11) 2 082 082 A

(21) Application No 8122495
(22) Date of filing 21 Jul 1981
(30) Priority data
(31) 80/26593
(32) 14 Aug 1980
(33) United Kingdom (GB)
(43) Application published
3 Mar 1982
(51) INT CL³
B01D 53/26 53/04
(52) Domestic classification
B1L 101 BF
(56) Documents cited
None
(58) Field of search
B1L
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(54) **Apparatus for purifying a gas**

(57) Gas purifying apparatus has two main drying beds 14 and 17 of solute (e.g. water-vapour) -removing material which are alternately used to purify a gas flow and then re-activated. Gas flow for bed re-activation flows through the main bed not being used, back through a supplementary bed (15,18) of the unused main bed to re-activate that bed also, through a central condenser 32 for removal of excess solute from the output gas flow from the supplementary bed being re-activated, and through a supplementary bed of the main bed being used for drying, in order to dry the output flow from the central condenser.

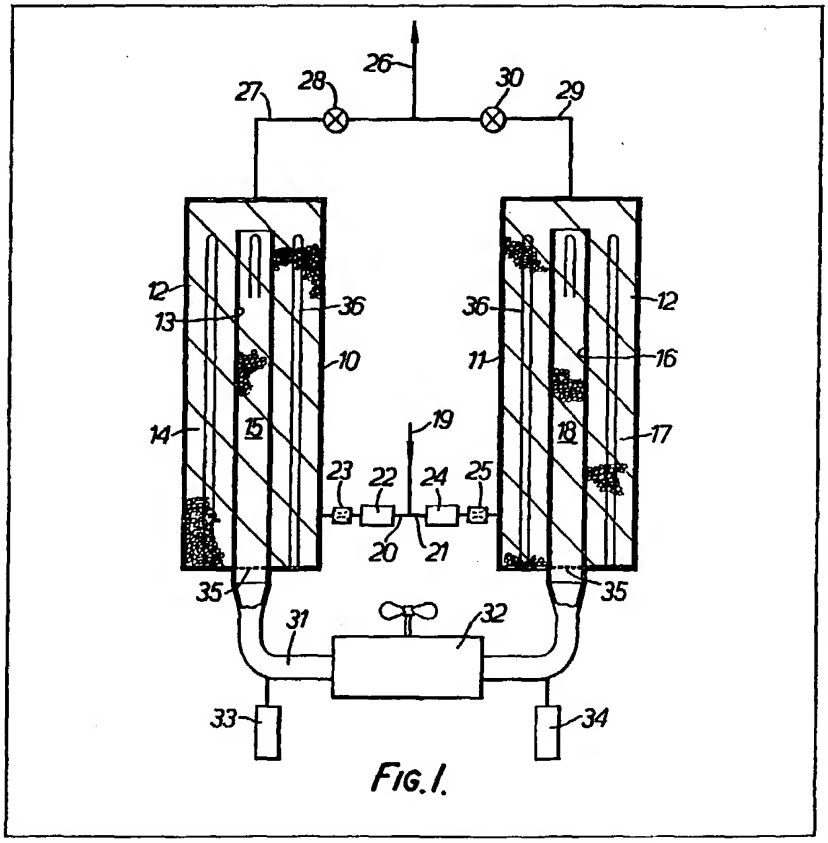

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

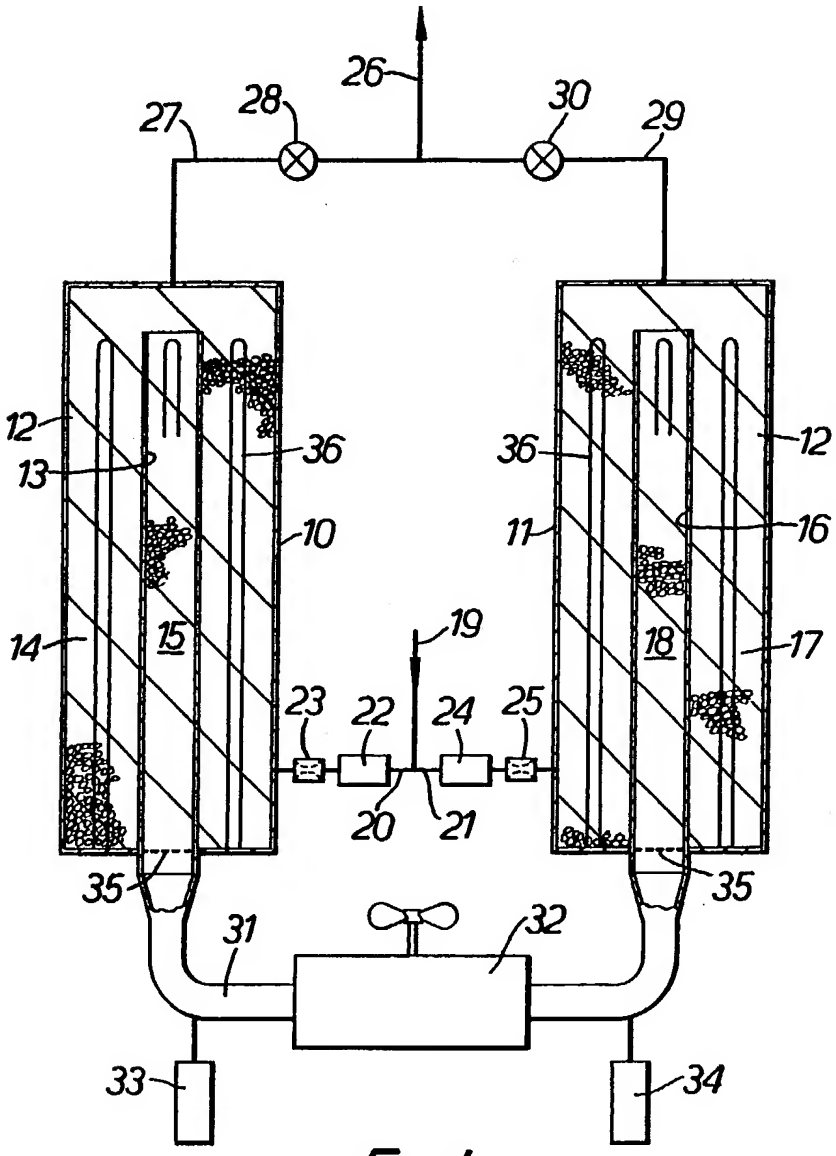
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FIG. 1.

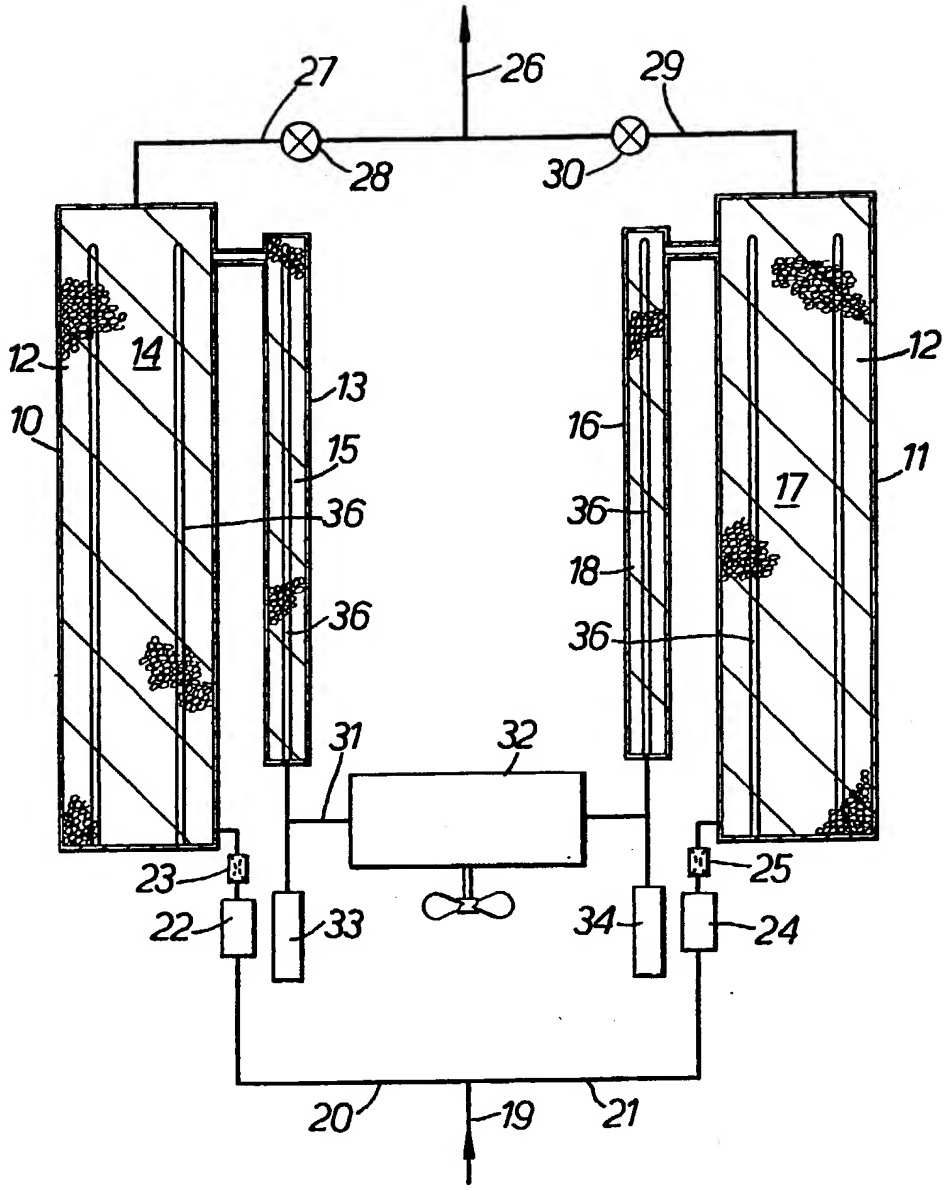
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FIG. 2.

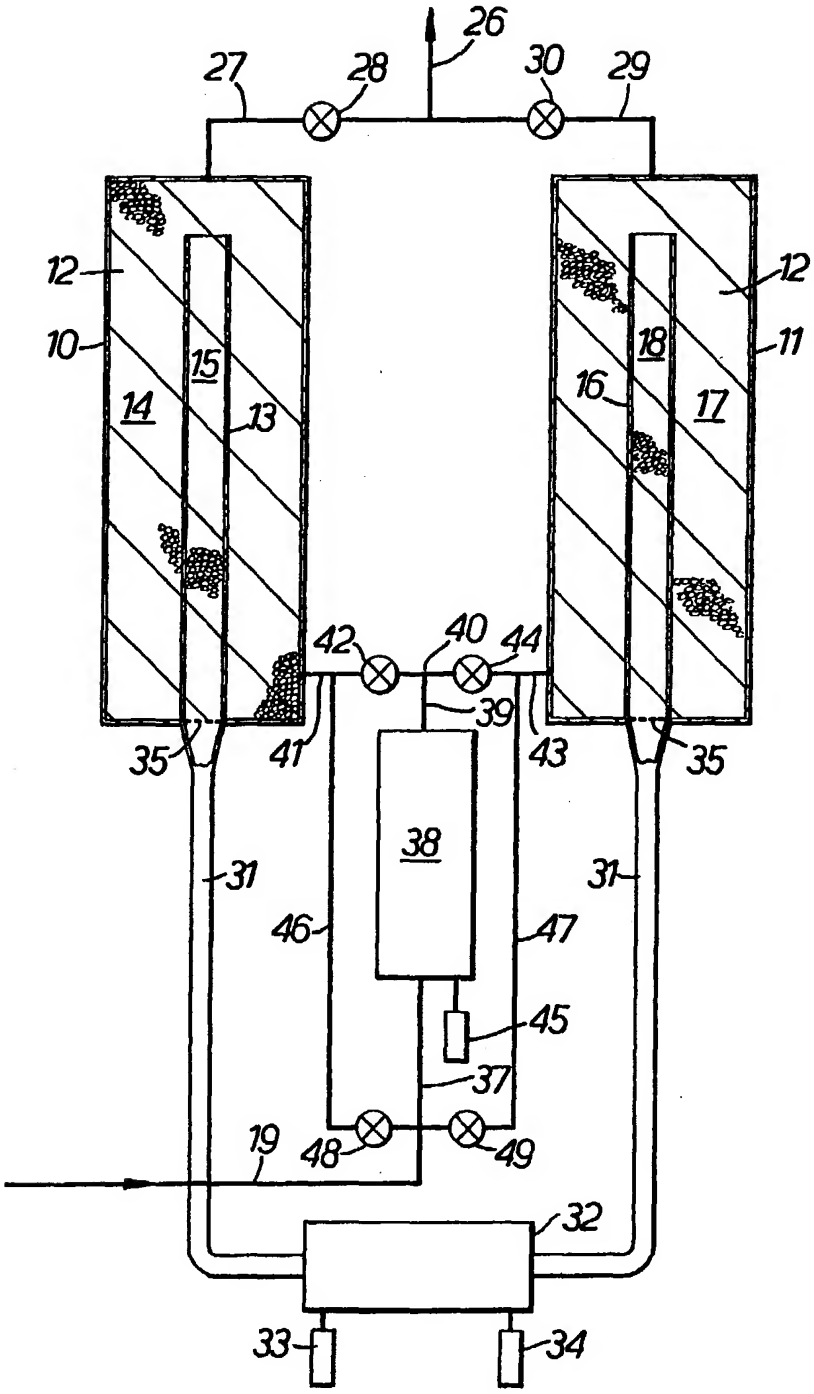
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FIG. 3.

SPECIFICATION

Apparatus for purifying a gas

This invention relates to gas purifying apparatus and more particularly but not exclusively concerns drying apparatus in which air moist with contained water vapour is flowed alternately through one or other of a pair of vessels containing water vapour-adsorbent, desiccant material. While one desiccant bed is drying the moist air, the other bed is being re-activated by flow therethrough of air which absorbs moisture from the desiccant.

Previous proposals for alternate re-activation of the desiccant beds comprise a method in which part of an output flow of dry air from that bed which is being used for the time being for drying is caused to flow through the other bed, being that which is under re-activation. Heaters in the desiccant bed being re-activated raise the temperature of the air, and hence its capacity to absorb moisture from the bed, and the air flow emerging from the bed is discharged to atmosphere. With careful design only about 6% of the flow of dried air need be employed for re-activation.

Another prior proposal is to divert a portion of the input flow of moist air through a heater to increase its capacity to absorb moisture, though the bed requiring re-activation, then through a condenser, and thereafer through the other bed. Because heating of the re-activation flow occurs remote from the bed rather than *in situ*, more heat is needed. In this respect the process is less efficient than the first prior proposal, mentioned above. Nevertheless, it does not have the disadvantage of the first proposal that some of the dry air flow is used for re-activation.

Besides the disadvantage that both these prior proposals consume an expensive commodity (heat or dry air) in achieving re-activation, they also suffer from the disadvantage that relatively sophisticated valves e.g. one or more 4-way valves, are required for automatic use and re-activation cycles. It is one object of the present invention to overcome or mitigate one or both of these disadvantages of the prior proposals.

According to the present invention there is provided apparatus for reducing the concentration of a condensable solute in a gaseous solvent in a temperature range within which the solute capacity of the solvent increases with temperature, said apparatus comprising a pair of beds of solute-removing material, a solute-laden gas, input connection to an input end of each of the beds, a solute-reduced gas, output connection to an output end of each of the beds, means to alternate the flow of solute-laden gas to be purified through one and then the other of the pair of beds, and means to re-activate the solute-removing material in each bed during a period after such bed has been employed to purify the solute-laden gas, wherein:

(i) each bed of said pair is a main bed having associated with it a supplementary bed, first ends of the supplementary beds being in fluid communication with the output ends of the corresponding main beds, and second ends of the supplementary beds being in fluid communication with opposite ends of a central condenser;

(ii) the said means to alternate the flow comprises valve means at the said output connection, whereby the main bed which is not being used for drying at any particular time is in fluid communication at its input end with the input flow of solute-laden gas and is in fluid communication at its output end with the output end of the other main bed of the pair via the supplementary bed of the main bed not being used for purifying, the central condenser and the other supplementary bed; and

(iii) heating means are provided to increase the solute capacity of the gas flowing through the main and supplementary bed of the bed not being used for purifying thereby to re-activate the material of the main and supplementary beds by reduction of the amount of solute contained therein, the condenser serving to remove the resultant increased solute content of the gas, and the supplementary bed of that main bed which is being used for purifying serving to purify the solute-saturated gaseous output flow from the central condenser and deliver it to the output connection.

Normally, the solute to be removed from the gas is water vapour, and the gas which is to be purified is air.

Preferably the main beds are cylindrical and arranged vertically and side-by-side, with the supplementary bed of each main bed being located along the central longitudinal axis of the main bed, open at its top end and connected at its bottom end to the central condenser.

The gas input connection can be to the base of each of the main beds and the purified gas output connection is then normally to the top end of each of the main beds.

The valve means of the said output connection can be a pair of simple valves caused to open and close alternately in accordance with the prescribed cycle of operation of the apparatus. Thus, impure gas may enter both main beds from the input connection and, in the bed being used for purification, flows directly through the length of the bed and through an open valve into the output connection. For the other bed, however, the associated valve closes the output connection, so any impure gas entering the bed must flow up the length of the bed, down the length of the associated supplementary bed, through the central condenser and up the length of the supplementary bed in the active bed, to reach the output connection through the open valve. Judicious application of heat to the bed not being used for purification will cause solute to be conveyed in this gas flow to the central condenser, and the condenser output is then dried in the supplementary bed of the drying bed before the condenser output flow is added to the main flow of solute-reduced gas. Generally, it will be convenient to provide the heat *in situ* but an alternative is to employ as input to the bed to be re-activated a hot output flow from an adjacent gas compressor.

For a better understanding of the invention, reference will now be made to the accompanying drawings, in which

Figures 1, 2 and *3* are flow diagrams of first, second and third embodiments of the invention respectively.

The apparatus of Figure 1 essentially comprises a pair of vertically arranged, cylindrical vessels 10 and 11 each of which contains a bed 12 of water-adsorbtive, silica gel, desiccant material. A cylindrical sleeve 13 in the vessel 10 and coaxial with it divided the bed 12 into an annular main bed 14 and an inner, supplementary bed 15. Likewise, a sleeve 16 in the vessel 12 creates a main bed 17 and supplementary bed 18.

An inlet connection 19 for compressed gas, moist with water vapour, is provided at the base of the vessels 10 and 11. The connection 19 is bifurcated to feed the base of vessel 10 through a conduit 20 and the base of vessel 11 through a further conduit 21. The conduit 20 is provided with a small heater 22 and a variable orifice 23, and the conduit 21 is provided with a similar small heater 24 and variable orifice 25, the functions of these heaters and orifices being explained below.

At the top of the vessels 10 and 11 there is provided a bifurcated output connection 26 connected to the top of vessel 10 by a conduit 27 including a valve 28, and connected to the top of vessel 11 by a conduit 29 including a similar valve 30. Control equipment (not shown) opens and closes the valves 28 and 30 alternately, causing the main flow of gas to be dried to pass through either the main bed 14 of the vessel 10 or the main bed 17 of the vessel 11.

The lower ends of the sleeves 13 and 16 are put in communication with one another by a conduit 31 in which is provided a central condenser 32. The usual water traps 33 and 34 are provided adjacent the two ends of the condenser 32. Screens 35 prevent downward flow of desiccant material in the sleeves 13 and 16. Heaters 36 are provided within the vessel 10 to heat the main bed 14 and supplementary bed 15 in that vessel, and further heaters 36 are provided in the vessel 11 to heat the main bed 17 and supplementary bed 18 therein.

The apparatus functions as follows.

With valve 28 open and valve 30 closed the main flow of moist gas is through the input connection 19, conduit 20, main bed 14, output conduit 27 and output connection 26. There is however an alternative flow path for the gas, this being through the input conduit 21, upwardly in the vessel 11 through the main bed 17 and downwardly through the supplementary bed 18, through the central condenser 32 and upwardly through the supplementary bed 15 of the vessel 10 being used for drying. This flow is utilised for re-activation of the desiccant material in the main bed 17 and supplementary bed 18 by actuating the heaters 36 in the vessel 11, thereby raising the temperature of the beds 17 and 18 (and thence the gas flowing through them), which increases the capacity of the gas to absorb moisture and results in a flow of moisture from the desiccant material in the vessel 11 in to the through flow of gas. The warm, wet gas passes through the screen 35 and to the condenser 32 where much of the moisture is condensed and collected in the water traps 33 and 34. The output flow of cold, saturated gas from the condenser 32 passes along the conduit 31 and is dried in its upward passage through the supplementary bed 15 in the vessel 10.

In general, there will be no need for adjustment of the variable orifice 25 to ensure that the desired proportions of gas flow through the two vessels 10 and 11, because the various conduits and flow passages can be so dimensioned as to achieve the desired balance at time when the apparatus is running at its rated output. However, if for any reason the apparatus is driven at an output only a fraction of its rated flow, the pressure difference between the input and output of the bed being used for drying may be insufficient to establish the required rate of gas flow through the bed being re-activated. In these circumstances, the variable orifice 23 can be actuated when the vessel 10 is being used for drying to increase the pressure difference between the input connection 19 and output connection 26, and likewise the orifice 25 can be actuated when the vessel 11 is used for drying.

The heaters 36 in the beds 17 and 18 being re-activated are supplemented by the heater 24, the function of which is to heat the input flow of gas sufficiently to prevent any adsorption of moisture from the gas on to the desiccant material immediately adjacent the junction of the input conduit 21 and the vessel 11. The heater 22 performs an analogous function for the vessel 10.

The apparatus operates according to a prescribed cycle so that, after a specified time, the heaters 36 and 24 are switched off, enabling the through flow of gas to cool the warm, dried beds 17 and 18 prior to their use for drying. Once these beds 17 and 18 have been cooled by continuing flow of gas therethrough the valve 28 is closed and the valve 30 opened, while at the same time the heaters 36 in the vessel 10 and the preheater 22 are actuated for re-activation of the beds in the vessel 10 in a manner described above in relation to vessel 11.

Figure 2 shows a variant of the embodiment of Figure 1, like components being identified by like references. The sleeve 13 and 16 containing the supplementary beds 15 and 18 respectively are spaced from the longitudinal axis of the vessels 10 and 11 respectively. This second embodiment is less preferred than the first because for sufficient heating of the desiccant material in the main and supplementary beds of the bed to be re-activated more energy is needed than in the first embodiment.

Figure 3 shows an embodiment in which, again, many components correspond with those of the first two embodiments and are identified by like references. In this third embodiment the desiccant vessels 10 and 11 do not contain heaters. Instead, re-activation of the desiccant material depends upon flow therethrough of the hot output flow from a gas compressor.

Thus, the flow of hot gas from the compressor enters the input connection 19, and part of the flow is through a conduit 37 to an input condenser 38 and on to a condenser output conduit 39 leading to a bifurcation 40. From here one branch 41 leads to the vessel 10 through an input valve 42 while the other

branch 43 leads to the vessel 11 through a further valve 44. The condenser 38 is provided with the normal water trap 45 and acts to remove moisture from the gas by cooling it.

The condenser input conduit 37 is provided with a first branch 46 which communicates with the input conduit 41 to the vessel 10, and a second branch 47 which communicates with the input conduit 43 of the vessel 11. The branch 46 has a valve 48 and the branch 47 has a valve 49.

The various valves operate as follows. When the beds of vessel 10 are to be employed for drying the valve 28 is open and the valve 30 is closed, as described previously. The valve 42 is open and the valve 44 is closed so that the main flow of gas to the drier passes to the vessel 10. Furthermore, the valve 49 is open and the valve 48 is closed so that a subsidiary flow of hot, moist, compressed gas is allowed to by-pass the condenser 38 and flow direct to the input 43 of the vessel 11 for re-activation of the desiccant material within it. In other respects, the operation of this embodiment is similar to that of the first two embodiments.

CLAIMS

1. Apparatus for reducing the concentration of a condensable solute in a gaseous solvent in a temperature range within which the solute capacity of the solvent increases with temperature, said apparatus comprising a pair of beds of solute-removing material, a solute-laden gas, input connection to an input end of each of the beds, a solute-reduced gas, output connection to an output end of each of the beds, means to alternate the flow of solute-laden gas to be purified through one and then the other of the pair of beds, and means to re-activate the solute-removing material in each bed during a period after such bed has been employed to purify the solute-laden gas, wherein:

(*i*) each bed of said pair is a main bed having associated with it a supplementary bed, first ends of the supplementary beds being in fluid communication with the output ends of the corresponding main beds, and second ends of the supplementary beds being in fluid communication with opposite ends of a central condenser;

(*ii*) the said means to alternate the flow comprises valve means at the said output connection, whereby the main bed which is not being used for drying at any particular time is in fluid communication at its input end with the input flow of solute-laden gas and is in fluid communication at its output end with the output end of the other main bed of the pair via the supplementary bed of the main bed not being used for purifying, the central condenser and the other supplementary bed; and

(*iii*) heating means are provided to increase the solute capacity of the gas flowing through the main and supplementary bed of the bed not being used for purifying thereby to re-activate the material of the main and supplementary beds by reduction of the amount of solute contained therein, the condenser serving to remove the resultant increased solute content of the gas, and the supplementary bed of that main bed which is being used for purifying serving to purify the solute-saturated gaseous output flow from the central condenser and deliver it to the output connection.

2. Apparatus as claimed in claim 1 wherein the beds of solute-removing material are of desiccant material.

3. Apparatus as claimed in claim 1 or 2 wherein the beds are vertically arranged and cylindrical, with the supplementary bed of each main bed being located along the central longitudinal axis of the main bed, open to the said main bed at an upper end thereof and connected at a lower end thereof to the central condenser, the input end of each main bed being at the lower end thereof and the output end of each main bed being at the upper end thereof.

4. Apparatus as claimed in any one of the preceding claims wherein said valve means comprises a first valve in a conduit between the output end of a first one of said main beds and the output connection, and a second valve in a conduit between the output end of a second one of said main beds and the output connection.

5. Apparatus as claimed in any one of the preceding claims wherein said heating means comprise a first heating element located within said first solute-removing bed and a second heating element located within said second bed, the first and second elements being capable of actuation alternately, in time with the alternation of the flow of gas to be purified between the first and second beds.

6. Apparatus as claimed in claim 5 comprising first and second supplementary heating elements which in use heat the flow of gas to that bed which is, for the time being, undergoing re-activation, thereby to prevent adsorption of solute from said flow by the solute-removing material of the bed undergoing re-activation in the region of the bed immediately adjacent the input end of the bed.

7. Apparatus as claimed in any one of claims 1 to 4, wherein said heating means comprise a gas input compressor which heats an input flow of gas to the apparatus, there being a condenser interposed between the input compressor and that main bed which is at any instant serving to purify the gas, which condenser cools the flow of gas before it enters the said main bed.

8. Apparatus as claimed in any one of the preceding claims wherein each supplementary bed is co-axial with its associated main bed.

9. Apparatus as claimed in any one of the preceding claims wherein each supplementary bed is located externally of its associated main bed.

10. Apparatus as claimed in any one of the preceding claims including first controllable means associated with the first main bed and second controllable means associated with the second main bed to increase the drop in pressure between the inlet connection and the outlet connection of the apparatus, the first means being actuated only when the first bed is in use for gas purification and the second means being actuated only when the second bed is in use for gas purification.

11. Apparatus as claimed in claim 10, wherein the first and second means are variable orifices

controlled by a programmable control device.

12. Apparatus for purifying a gas substantially as hereinbefore described with reference to, and as shown in, any one of the Figures of the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1982.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.